5-1969

The Capability of the Utah State University Drainage Farm as an Irrigation and Drainage Demonstration Project

Mario Perez

THE CAPABILITY OF THE UTAH STATE UNIVERSITY DRAINAGE FARM AS AN IRRIGATION AND DRAINAGE DEMONSTRATION PROJECT

by

Mario Perez

A report submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Agronomy

Plan B

UTAH STATE UNIVERSITY
Logan, Utah

1969

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

Figure | Page

INTRODUCTION

There are in Cache County 20,000 acres of poorly drained land similar in many respects to the other wet lands of Utah, estimated to total a half million acres, which are mostly natural meadows. In order to turn those lands more productive either for forage or other crops, adequate management practices must be developed regarding control of the surface water, leaching, reduction of artesian pressure, and improved water application techniques.

Studies carried out at the Utah State University Drainage Farm, west of Logan, Utah, which is representative of those poorly drained lands, have already shown successful ways for these areas to be improved.

GEOLOGIC HISTORY RELATED TO THE AREA

Cache Valley is located in the northern part of Utah and southern Idaho. The floor of the valley is comparatively level. The valley is surrounded by mountains or high elevations except for the low fault notch where the drainage issues to the southwest. The valley is bounded on the east by the Bear River Range of mountains, which rises to an elevation of from 8,000 to 9,000 feet with individual peeks rising considerably above 9,000 feet.

The soil of the valley is all transported and results from stream or lake deposition.

The origin of the valley is structural and is involved in a faulting system which extends north and south. The mountain structure is a broad syncline with the western limb exposed along the east edge of the valley. Two nearly parallel faults traverse the east edge of the valley, making a definite escarpment from East Canyon to Green Canyon, and definite facets show the position and angle of the movement.

The amount of vertical movement has not been too well measured, but definitely extends into several thousand feet. The movement has taken place very gradually over a long period, and the mountain range has been eroded during the process.

The Wellsville Range on the west side of the valley contains the same geological formation as the mountains on the east side. The strata generally dip to the east in the south part of the valley, but are broken by two north-south faults, one near the west edge of the valley floor, best marked by the springs that come out along its extension. The second fault is farther west, well up on the flank of the range. This fault is easily seen by the change in dip. It is associated with many minor faults running at different angles.

As the west faulting system extends northward along the valley, it becomes more complex. The fault depression extends northward, and the low pass through which the old lake drainage issued marks the general position. The drainage of the water out of Cache Valley to the west is along a fault line.

Coincident with the faulting, the floor of the valley has relatively settled. The process has been slow, and the movement has not been uniform at all points. The relative settling of the valley floor has been greater on the east side than on the west. This is evidenced by the showing of the Salt Lake formation along the western margin of the valley, but in no place has it been detected on the east margin.

The Salt Lake formation is a light colored shallow water deposit of possible oligocene or pliocene age and extends over considerable area in northern Utah, southern Idaho, and southwestern Wyoming. It is variable in different areas. On the west side of Cache Valley, it is found as a narrow irregular fringe unconformably on the older rock, extending from Avon northward around the west edge of the valley.

Another evidence of the irregular settling is a section from an oil prospecting well, in Section 4 T 11 N, R 1 W SLB&M, which found bed rock at 580 feet, while a well 1 1/2 miles north was still in unconsolidated sediments at 1,150 feet.

The only well, which has been driven through the entire sedimentary accumulation, is a 12-inch pipe in the northwest corner of Section 25 T 13 N, R 1 W SLB&M, which is a point near the center of the valley. Only partially cemented material was found in any part of the column. The log indicates the history of the valley fill and the resting periods in the process. The log shows peat beds at depths of 155 feet, 430 feet, 648 feet, 1,135 feet, and 1,200 feet. It is not presumed that these peat beds extend over the whole area, but the amount showed in the drill hole does seem to warrant the statement that such material marks a quiet water surface for each of the peat deposits for sufficiently long periods to allow vegetative growth and accumulation.

Conversely, it may be inferred that the rate of settlement of the valley floor during the accumulations of the clays, sands, gravels, etc. was more rapid than in the peat zones.

The well gives significant data with reference with the ground water of the valley. The sinking of the valley floor below the mountain ranges makes the valley a definitely tight basin which holds water to the height of its structural outlet, which is at an elevation of 4,400 feet where Bear River issues westward out of Cache Valley through the Bear River Canyon. The elevation of the surface where the well is drilled is 4,425 feet. The elevation of the bottom of the well would be 2,950 feet. This makes a basin whose depth is approximately 1,400 feet below the structural outlet. The driller reported the well made little water except from the coarse gravels. Much gas was encountered, and water was often thrown out of the well by gas pressure, but actual water flow from static head did not occur above 740 feet. Water flowed at 740 feet, 825 feet and 940 feet to 970 feet. None of the flows were strong.

At 1,065 feet hot water was encountered. The flow was not strong. When the drill reached 20 feet of coarse gravel horizon at 1,351 feet, there was a strong artesian flow of six-second feet of clear water at the top of an 18-foot pipe which was added. The temperature of the water was 62 F.

As the well was driven deeper, the flow was partially cut off, and when the well reached solid rock the flow was less than half. The behavior of the well clearly indicates that while it is drilled almost entirely within the water-table, water in quantity can only be obtained from coarse sand or gravel aquifers.

The general history of the materials making up the valley fill would indicate settling movement with resting surface periods in the peat zones, and at each such period the level would approximate the elevation of the drainage outlet of the valley (4,400 feet).

The indications are that during the pre-Bonneville period the water did not rise appreciably above the outlet and the drainage was into the Great Basin, which is not recorded as having high elevations of water previous to the Bonneville period.

The stream flow into the valley in the pre-Bonneville and early Bonneville period is of fundamental importance in the availability of ground water.

Streams entered the valley through the mouths of the present canyons and flowed out to or beyond the center of the valley, and gravels and sands of various sizes were deposited along the stream channels. As the water rose, the coarse deposits became buried and always extended to the valley intake and, thus, aquifers were formed which continued to be fed from the stream source and are now the most important source of the ground water available in the valley. Not only the amount of ground water is important from this source but the static head or pressure head is influenced by the height to which the aquifer is filled.

Lake Bonneville, named after Captain Bonneville, came into existence during the pleistocene or glacial epoch. It came with a change in climate, greatly increased rainfall, decreased evaporation, and lower temperature. The streams were greatly swollen; alpine glaciers formed in many of the upper reaches of the streams. The water rose to the height of 5,150 feet, filling the whole Great Basin. The large lake at its highest level had an area of 19,750 square miles, a maximum depth of 1,080 feet.

Cache Valley was a bay to the large lake. As the lake rose, there was a continued upstream positioning of the coarse material deposited by the streams.

During the Bonneville epoch, the low part of the ridge between Cache Valley and Box Elder was submerged so that the waters of the

Cache Bay could mix freely with the waters of the larger lake.

The wave-cut terrace at the high level of Bonneville shoreline is traceable continuously about Cache Valley to the vicinity of Red Rock pass.

With the establishment of an outlet, the lake level descended slowly and irregularly in conformity to the epochal and seasonal water supply, and the level finally fell to the level of the outlet (4,770 feet) or what has been termed the Provo stage. This stage is 375 feet lower than the Bonneville shoreline. At the Provo stage, there was only the Bear River gorge as connection between the large lake and the Cache Bay.

During the Provo stage, the large lake developed sufficient lime concentration that calcareous tufa was deposited along the shoreline. No deposits have been detected in Cache Valley. This is accounted for by the large inflow of water from the Bear River drainage.

While the water in the big lake was concentrated and salted, the Cache Valley water remained fresh. This had an important effect on the character of the soils.

As soon as the water from high Bonneville stage began to lower, the streams entering the valley began to cut into the debris, which had accumulated within the canyon walls, and this material moved forward as the water lowered.

Logan Delta, formed at the mouth of the canyon on the east side of the valley, records the deposition, classification and character of the material, and the history of its building. The surface of the delta has a slope of less than 1 percent from its apex to the edge. It is about 100 feet thick near the mouth of the canyon and 400 to 600 feet thick on the west margin of the Provo stage of the delta. The debris removed from the upper delta was reclassified and redeposited into smaller deltas below. This happened no less than 10 times.

The important phenomena with reference to ground water is that the stream channels have again eroded down to the higher exposure of the stream gravel or coarse sand which was deposited at the time when the stream extended out onto or near the middle of the valley. The upper deposits of coarse materials are so exposed that they become aquifers or water intakes, allowing the water to move underground under fine strata out of the wide part of the valley. The position and elevation of the water on the aquifer allow the building up of a pressure head which places the water under static head. The effectiveness of the static head depends on position, elevation, and friction of the water passage through the material.

Artesian pressure seems to depend entirely on the water intake through the aquifers and is little effected by the accumulation of surface water on the floor of the valley. The surface water may raise the water-table and thus affect the water level in surface wells, but the head which produces pressure in the artesian flow has a different source and is largely independent of the position of the surface water-table.

SOILS

Thirty-four deep borings were made on the Utah State University Drainage Farm. These borings were made with the Soil Conservation Service drainage machine and were recorded as follows:

Record of Soil Borings on U.S.U. Drainage Farm

Station #1 - OOE - OOS

0-6'	gray silty clay, moist
6-9 1/2'	brown clay, moist
9 1/2-10'	gray sand layer, free water
10-11 1/2'	gray silty clay with some clay loam stratification, wet

Strongest mottling comes in 6 feet to 9 1/2 feet

Station #2 - OOE - 440S

0-4'	gray moist silty clay
4-10'	brown moist clay, highly mottled
10-11'	gray wet stratified silty clay and silty clay loam. Some lenses very fine sand.

Free water 10'

Station #3 - 440E - OOS

0-4'	moist silty clay
4-9 1/2'	moist clay, brown and mottled
9 1/2-12'	stratified gray silty clay loam and clay with thin sandy layers, wet.

Free water 9 1/2'

Station #4 - 880E - 00S

0-1 1/2'	gray silty clay loam
1 1/2-4 1/2'	gray moist silty clay
4 1/2-10'	brown moist, mottled clay
10-12'	gray stratified wet silty clay loam, silty clay and sandy lenses.

Free water 10'

Station #5 - 1320E - 00S

0-1 1/2'	silty clay loam, dark grayish brown
1 1/2-4 1/2'	gray clay, gleyed, moist
4 1/2-9 1/2'	brown, highly mottled moist clay
9 1/2-11 1/2'	gray stratified silty clay loam and some sand and clay layers.

Free water 9 1/2'

Station #6 - 1760E - 00S

0-2'	moist dark gray clay loam
2-4'	moist light gray gleyed clay
4-11'	moist brown mottled clay
11-12'	gray stratified silty clay loam, clay and some sandy layers.

Free water 11'

Station #7 - 1760E - 440S

0-1'	dark gray moist silty clay loam
1-3'	gleyed gray moist silty clay loam
3-5'	gleyed moist light gray clay
5-11'	moist brown mottled clay
11-12'	stratified moist silty clay loam, clay and some sandy layers,

Free water 11'. Sampled.

Station #8 - 1320E - 440S

0-1 1/2'	dark gray moist silty clay loam
1 1/2-4 1/2'	gleyed light gray clay, moist
4 1/2-10'	moist brown mottled clay
10-12'	gray stratified clay loam, clay, some sandy layers.

Free water 10'

Station #9 - 880E - 440S

0-1 1/2'	dark gray silty clay loam, moist
1 1/2-4 1/2'	gray gleyed clay, moist
4 1/2-11'	brown mottled moist clay
11-12'	stratified clay, clay loam, and thin sandy layer.

Free water 10'

Station #10 - 880E - 880S

0-2'	dark gray silty clay loam, moist
2-4 1/2'	gray gleyed moist clay
4 1/2-9 1/2'	brown moist mottled clay
9 1/2-12'	gray stratified clay loam, clay and some sandy layers.

Free water 9 1/2'

Station #11 - 440E - 440S

0-1 1/2'	dark gray silty clay loam
1 1/2-4 1/2'	gray gleyed moist clay
4 1/2-9'	brown moist mottled clay
9-12'	stratified clay loam, clay and thin sandy layers.

Free water 9 1/2'

Station #12 - 1320E - 880S

0-2'	moist dark silty clay loam
2-5'	moist gleyed gray clay
5-10 1/2'	moist brown mottled clay
10 1/2-12'	wet gray stratified silty clay loam, clay, and sandy layers.

Free water 10'

Station #13 - 1760E - 880S

0-1 1/2'	dark gray moist silty clay loam
1 1/2-7'	gray gleyed moist clay
7-11 1/2'	brown mottled moist clay
11 1/2-12 1/2'	stratified silty clay loam, clay

Free water 10'

Station #14 - 2200E - 880S

0-1 1/2'	moist dark gray silty clay loam
1 1/2-7'	gleyed light gray moist clay
7-12 1/2'	gleyed moist gray clay, some pink soil--mottled

Couldn't determine free water because dripped in from surface.

Station #15 - 2200E - 440S

0-1'	dark gray moist loam
1-4'	semi-soupy gray to brown loam
4-7 1/2'	light gray gleyed clay, moist
7 1/2-12'	grayish brown mottled clay, moist

Couldn't determine free water.

Station #16 - 2640E - 440S

0-1'	dark gray moist clay loam
1-3'	grayish brown semi-soupy loam
3-6'	green gleyed moist clay, brown mottles
6-10'	brown moist clay, green mottles
10-12'	brown moist mottled clay

Couldn't determine free water.

Station #17 - 300E - 440S

0-1'	dark gray moist silty clay loam
1-3 1/2'	gray moist clay loam
3 1/2-5'	gleyed light gray clay, moist
5-7 1/2'	gray clay, brown, some green mottles, moist clay
7 1/2-10'	brown mottled, moist clay
10-12'	stratified clay loam, clay and sandy layers

Couldn't determine free water.

Station #18 - 3000E - 00S

0-2 1/2'	dark gray moist clay loam
2 1/2-4 1/2'	gray gleyed clay, moist
4 1/2-9 1/2'	stratified clay loam and sandy layers

Free water 10 1/2'

Station #19 - 3000E - 880S

0-1'	dark gray moist clay loam
1-3'	gray clay loam, moist
3-5'	moist gray gleyed clay
5-6 1/2'	moist gray mottled clay
6 1/2-10'	moist brown mottled clay
10-12'	stratified clay loam, clay and some sandy layers

Free water 6' near ditch.

Station #20 - 3300E - 1320S

0-1/2'	dark gray moist clay loam
1/2-3 1/2'	gray clay loam, moist
3 1/2-4'	black moist clay
4-6'	gray gleyed moist clay
6-11'	mixed green and brown moist clay
11-12'	stratified clay loam, clay and sandy layers

Free water 3 1/2' near ditch

Station #21 - 880S - 00E

0-24"	gray silty clay loam
24-54"	gray silty clay, some fine mottling
4 1/2-7 1/2'	gray silty clay with many coarse prominent mottles
7 1/2-9 1/2'	silty clay, brown or reddish brown, gray and yellow coarse prominent mottles
9 1/2-12'	stratified silty clay loam, thin layers of sandy material, greenish--olive color

Watertable 11 1/4'

Station #22 - 880S - 440E

0-1 1/2'	gray silty clay loam
1 1/2-3'	gray clay, many coarse prominent mottles
3-4 1/2'	reddish brown clay, some mottling
4 1/2-9'	reddish brown clay, many coarse prominent mottles
9-11'	green or olive silty clay loam, stratified with sandier material

Watertable 11 1/2'

Station #23 - 1320S - 00E

0-18"	dark gray, heavy silt clay loam
1 1/2-5 1/2'	light gray clay, few fine distinct mottles
5 1/2-9 1/2'	reddish brown clay, many coarse prominent brown and green mottles
9 1/2-11 1/2'	olive gray sandy clay loam

Watertable 11 1/2'

Station #24 - 1320S - 440E

0-1 1/2'	gray heavy silty clay loam
1 1/2-4'	light gray clay, few fine distinct mottles
4-5 1/2'	light brown clay, few fine distinct mottles
5 1/2-9 1/2'	reddish brown clay, many coarse prominent mottles
9 1/2-11 1/2'	stratified olive sandy clay loam, silty clay loam, thin sand strata

Watertable 10 1/2'

Station #25 - 1320S - 880E

0-1'	dark gray clay
1-3'	light gray clay
3-5'	brown clay, few fine distinct mottles
5-9'	reddish brown clay, many coarse prominent reddish brown mottles
9-12'	olive gray--silty clay loam--stratified with thin strata of olive sandy loam

Watertable 10 1/2'

Station #26 - 1320E - 13208

0-1'	dark gray silty clay loam
1-3'	light gray clay
3-5'	light brown clay, olive mottling
5-9'	brown clay, many coarse prominent mottles
9-11'	stratified silty clay loam and sandy loam

Watertable 11 1/2'

Station #27 - 1760E - 1320S

0-2'	dark gray silty clay loam
2-3'	light gray clay (some mottling)
3-4'	light gray and brown (mixed) clay
4-7'	light gray and brown (mixed) clay (greenish)
7-9'	brown clay--mottled
9-11'	gray silty clay--mottled

Perched water 2-3 feet--water 2 feet

Station #28 - 2200E - 1320S

0-1'	dark gray silty clay loam
1-5'	light gray clay
5-6'	light gray clay--mottled
6-8'	brown clay--strongly mottled
8-9'	brown and light gray clay
9-10'	brown silty clay
10-11'	brown clay--strongly mottled
11'	olive gray stratified silty clay and silty clay loam, some mottling

Water 11'

Station #29 - 2640 - 1320S

0-1/2'	sod
1/2-3 1/2'	light gray silty clay loam--wet
3 1/2-4'	gleyed light clay--free water
4-7'	light green clay
7-7 1/2'	light green-brown mottled clay
7 1/2-9 1/2'	dark green tight clay
9 1/2-11'	dark green and bluish silty clay

Water 2 1/2'

Station #30 - 2640E - 880S

0-1/2'	sod
1/2-3 1/2'	light gray silty clay loam
3 1/2-5'	gleyed tight clay
5-6'	gleyed tight clay, some mottling
6-7'	light green tight clay
7-8'	green tight clay, strongly mottled
8-9'	brown clay
9-10'	brown and green mottled clay
10-11'	light green and bluish clay

No water when dry

Station #31 - 3520E - 1320S

0-1 1/2'	dark gray clay loam to clay
1 1/2-2 1/2'	light gray clay
2 1/2-3 1/2'	brown and gray tight clay
3 1/2-6'	brown tight clay (some mottles)
6-8 1/2'	brown and gray tight clay (much mottled)
8 1/2-11'	green wet silty clay loam

Water 10 1/2'

Station #32 - 3580E - 880S (Nearer 1000S)

0-2'	marly
2-3'	light gray clay
	Water 3'
3-4'	light gray tight clay
4-5'	light gray and brown tight mottled clay
5-6'	tight brown clay (some white mottles)
6-8'	tight brown and green clay
8-9'	tight green clay
9-10'	tight light gray clay
10-11'	green clay
Water 2'	

Station #33 - 3520E - 440S

0-2'	light gray clay or silty clay loam
2-3'	light gray clay
3-4'	light gray tight clay
4-6'	brown tight clay--mottled
6-6 1/2'	tight clay--strong green and rust mottles
6 1/2-9'	tight brown clay--some mottling
9-10'	light gray clay
10-11'	green silty clay loam
Water 11'	

Station #34 - 3520E -00S

0-2'	dark gray silty clay loam
2-4'	light gray tight clay
4-8'	brown tight clay (some mottles)
8-9'	brown clay (some mottles)
9-11'	green silty loam to silty clay loam

Water 11' (9, p. 1-6)

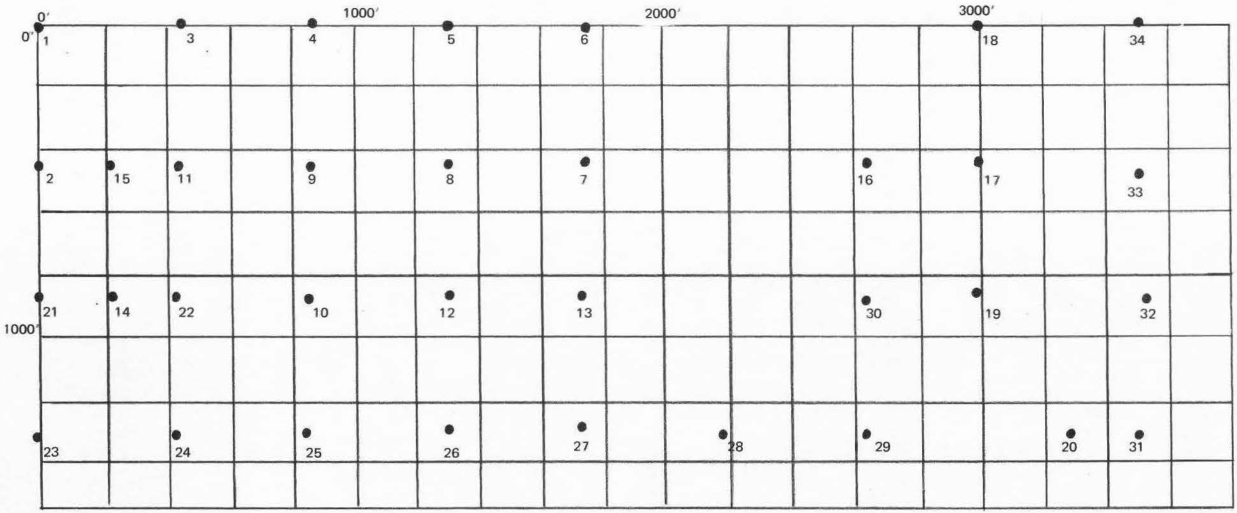
Analytical data for the location No. 8 are in Table 1. Figure 1 shows the sampling locations.

Table 1. Sodium analysis report

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Soils Laboratory

Area U.S.U. Drainage Farm — District of Survey U.S.U. Drainage Farm
Collected by Wilson & Olsen — Date Oct. 1957 — Analyzed by James P. Thorne — Date May 12, 1958

Lab No.	Organic matter	Depth	pH		Total soluble salts	Sat. ext. Cond.	Exch. Na	Base exch. cap.	Exch. Na.	Moist at Sat.	Lime $CaCO_3$	Mech. composition			Gypsum
			Paste	1:5	%	$KX10^3$	Me/100g	Me/100g	%	%	%	Sand %	Silt %	Clay .002 %	%
U573448	7.34	0-10	8.0	8.7	.08	2.8	.83	21.5	4	81	69.7	15	59	26	1
U573449	2.61	10-20	8.3	9.1	.07	2.2	.75	12.7	6	60	82.2	16	57	27	1
U573450	1.51	20-36	8.3	9.3	.09	2.5	1.53	14.3	11	51	72.0	13	59	28	1
U573451	.58	36-48	8.3	9.5	.25	3.3	3.9	18.4	21	79	53.9	2	37	61	1
U573452	.43	48-60	8.0	9.3	.34	4.4	5.2	21.3	24	89	42.6	1	38	61	1
U573453	.39	60-72	8.3	9.4	.34	3.8	5.1	21.6	23	86	43.7	1	42	57	1
U573454	.28	72-84	8.4	9.7	.42	3.8	5.6	21.2	26	86	32.4	1	46	53	1
U573455	.29	84-96	8.2	9.4	.39	5.0	5.4	22.0	25	81	27.5	1	49	49	1
U573456	.26	96-108	8.4	9.4	.35	4.6	3.9	22.6	17	87	24.0	1	47	52	1
U573457	.31	109-120	8.1	9.5	.35	5.3	5.5	24.6	22	80	24.5	3	50	47	1
U573458	.34	120-132	8.1	9.4	.21	4.0	4.6	21.4	22	75	34.9	1	63	36	1
U573459	.62	132-144	8.0	9.4	.25	4.4	4.2	16.3	26	61	34.5	2	70	28	1



N

Figure 1. Soil sampling locations, USU Drainage Farm, October 1957.

The following soils are present in the Drainage Farm according to the Soil Conservation Service classification. Figure 2 shows the approximate boundaries of the soil series, and Figure 3 shows the depths of workable soil.

IIw2 Ir 31/A-60 Greenson loan 0-3 percent deep soil, moderately well and imperfectly drained, medium texture calcareous soil. The depth of water-table is from 30 to 60 inches, moderate permeability; plant roots penetrate easily to the water-table; it holds 1.8 to 2.0 inches of water per foot of depth, slow surface runoff. Erosion hazard is none to slight. The substratum is slowly permeable. Dominant problem is water-table.

IVw25 SL 21/A Salt Lake Silty clay 0-1 percent. This is a deep very poorly drained soil, fine textured, salt and alkali affected. The water-table varies from ponded to about 30 inches in depth, very slow permeability. Roots penetrate to water-table with moderate difficulty. Soil used for meadow pasture and hay. Drainage, reclamation, and improved water application are the main management problems.

IIIw2 and IVw2.5 Ap 31-Lg 21/A-13 Airport-Salt Lake complex 0-1 percent, 60 percent Airport silt loam at elevated areas and 40 percent Salt Lake silty clay in the depressions. Most of the unit is native pasture. In Airport soil, the water-table is within 10 to 20 inches of the surface most of the time; the permeability is slow; the plant roots are shallow because of high concentration of salt and alkali in the subsoil; water holding capacity is about 1.8 to 2.0 inches per foot. Tillage is moderately difficult.

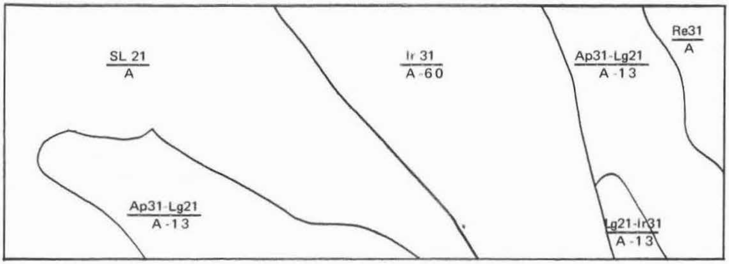


Figure 2. Approximate boundaries of the soil series, USU Drainage Farm.

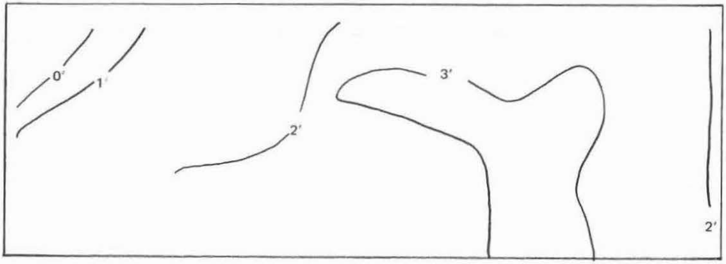


Figure 3. Contour lines of depths of workable soil to silty clay or finer textures.

IIIw1 Re 31/A Roshe Silt Loam 0-1 percent deep soil poorly drained, medium textured black soils. In places, peaty layer up to 2 inches occurs on the surface; depth to the water-table is 0 to 36 inches. In places the subsoil contains lime, causing the soil to be weakly cemented. Very strong calcareous and moderately alkaline soil is moderately permeable and will hold about 1.6 to 1.8 inches per foot. Roots penetrate the soil easily, mainly native meadow pasture unless drained (2).

SURFACE WATER

All water-logged lands, whether or not impregnated with alkali, are improved for ordinary crops by lowering the water-table. This means a permanent lowering under the farmer's control so that a rise of water above a given elevation in the soil for any length of time may be wholly prevented. The first step in lowering the water-table is to learn the source of the water that caused it to rise. In isolated cases in small tracts, it is sometimes possible for one farmer alone, or a small group of farmers, to find the water source and cut it off by construction of one or more intercepting ditches or drains. Usually in irrigated regions, small water-logged areas are caused by surface or underground water flowing to them from higher irrigated lands or from canals, ponds, or reservoirs. The farmer whose holdings are located within large or comparatively level water-logged land cannot, as a rule, lower the water-table by his own efforts. For such areas, community action is essential (3).

In 1957, efforts were made to control surface water by confining it to existing ditches and by constructing new ditches. In June 1958, a long open drain was constructed and connected to a natural drainage channel. After completion of the drain, surface water which had previously flooded the farm was collected in ditches and conveyed to the drain. During the winter, 1958-59, the water-table began dropping and continued to do so until in some places of the farm it was below the bottom of the drain.

During the winter, evaporation and transpiration is near zero, and the dropping water-table could not be explained in this way. The water-table could not be moving downward below 10 feet since there is a measurable upward gradient from a depth of 40 feet to about 10 feet. A possible explanation is that the water moves horizontally through a permeable layer at a depth of about 10 feet. The rate of drop is greater when the water-table is near the ground surface, being about 1 foot per week. At a depth of 4 to 5 feet the rate of drop decreases to about one-half a foot per month or less.

With a heavy application of irrigation water, the soil would again become saturated and a rise in water-table would result, thus indicating the close relation between the surface irrigation conditions and the drainage problem.

Part of the blame for high water-tables existing in Cache Valley as well as similar areas in the state has been placed upon upward movement of water from the artesian aquifer. The continued drop of the water-table during the winter months indicates, however, that the quantity of upward moving water is quite small. This is further indicated by the small amount of drainage water flowing in the open drain.

Using previous estimates of the rate of upward flow, the amount of water flowing in the open drain should have been several times greater than the amount actually measured.

The conclusion that the amount of upward flowing water is extremely small is supported by other evidence. At Logan Airport, just 2 miles away, an extensive tile drainage system remains dry most of the year. Water flows in these drains only after periods of rain (1).

ARTESIAN AQUIFERS

The upward movement of the water, although of little consequence so far as the amount of water is concerned, does make leaching and drainage more difficult. Water applied to the surface moves down until it reaches the water-table and then can only move off in a horizontal direction. Because of the flat slope of the land, the rate of movement in the horizontal direction is slow.

Initial evaluation work included installing piezometer batteries on a 500 foot grid over the entire farm. Each battery consisterd of four 3/8 inch pipe driven to depths of 10, 20, 30, and 40 feet. At each piezometer battery there was also a 10 foot deep auger hole for the purpose of measuring the water-table. Pressure readings from these piezometers showed a movement of water upward through the ground. The bottom of the 40 foot piezometer is in the artesian aquifer, and water in these piezometers rises to heights varying from 3 to 12 feet above the ground surface. The water levels in the 30, 20, and 10 foot piezometers are successively lower; the water level in the 10 foot piezometer is very close to that of the adjacent auger hole in most cases.

Figure 4 shows variations of artesian pressure and water-table during 1957-1959 in one of the piezometer batteries (1).

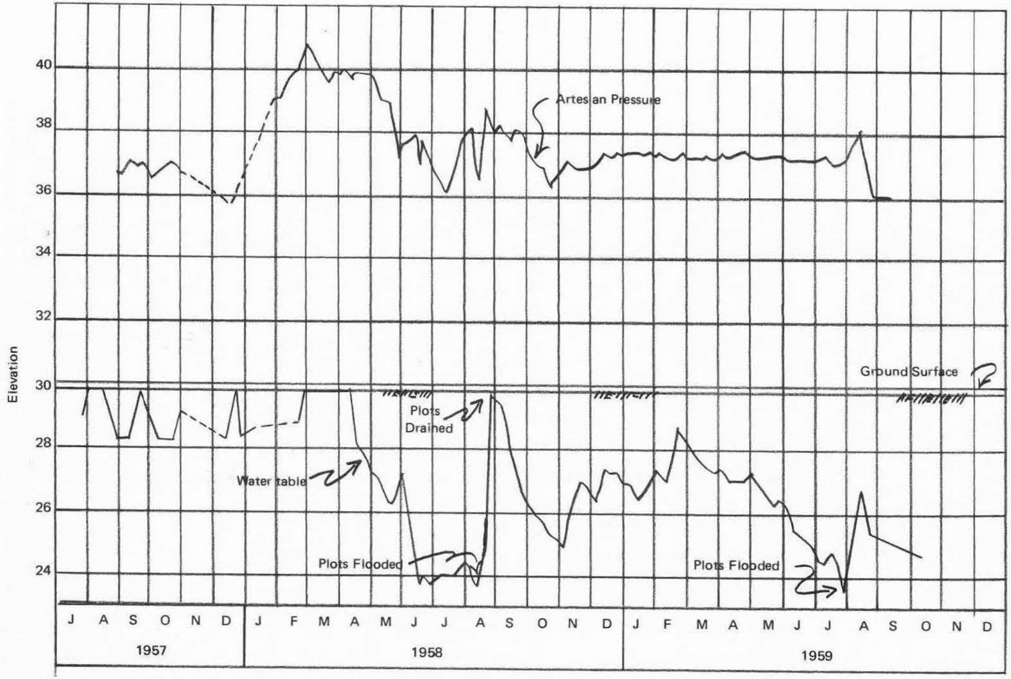


Figure 4. Continuous record of water level readings for a typical piezometer battery.

MOLE DRAIN

Probably the mole drain is the cheapest type of sub-surface drain device. Mole drains have been used with success in some soils in humid areas; however, they are not permanent installations. In an effort to protect the mole drain or to prolong its functional life, various research projects have been carried on to develop a liner for the drain. Among those tested, plastic liners have merit.

In 1959, a system of mole drains was installed on the Utah State University Drainage Farm to determine the suitability of this type of drainage. Part of the moles were installed with a thin plastic liner, whereas others were left unlined. Mole spacings of 20, 30, and 40 feet were used. The depth averaged 22 inches for those lined with plastic and 28 inches for the unlined moles. The difference in depth was due primarily to the difference in power required when the plastic lining device was used. At the time the moles were installed, the water-table was below 4 feet; the soil was dry and had a tendency to crumble, resulting in greater power requirements and a less stable mole.

Lined and unlined moles were effective in removing water and salt from the soil during the initial period of leaching and continuous flooding.

Leaching made a reduction in the salt content of the soil amounting to about 2,500 ppm, and after the initial flooding the drainage water had about the same salt content as the water used for flooding. Unlined drains failed after the initial period, whereas the lined drains operated through the flooding and freezing cycles of one winter.

The moles did not begin to flow until the water-table was about 2 feet above the drain. At about the same time the flow began, the ground surface became "slick" and water accumulated.

Reversed leaching was tried forcing the water through the soil from a tile placed at 30 inches depth. The salt was thus removed up through the soil and allowed to run off the surface. Preliminary results show that reversed leaching was more effective in salt removal and used less water than conventional leaching in this pilot experiment (1).

GRASS AND LEGUME EXPERIMENTS

Many grasses and legumes were tested in an experiment planted May 5, 1960 and evaluated in August 1961. Table 2 gives the results.

Response to phosphorus and nitrogen application was observed in alta fescue, Reed canarygrass and a mixture of bromegrass, Reed canarygrass, alsike clover, alta fescue, and alfalfa in an experiment planted in June 1962.

A new planting of a mixture was made in May 1964 adjacent to the former experiment and over the lined mole drains. This time, gypsum and sulfur effects were tested combined with nitrogen and phosphorus application. The mixture was of the same composition as the one used in the 1962 experiment.

In 1965, yields for both 1962 and 1964 plants were recorded. The data are given in Tables 3 and 4 (7).

Table 2. Grass and legume forage nursery, Utah State University Drainage Farm

Strain or variety	Stand[a] reps. 1	2	3	Ave.	Growth[b] reps. 1	2	3	Ave.	Rating[c] reps. 1	2	3	Ave.
Smooth bromegrass												
Saratoga	90	50	70	70	90	50	50	63	1	1	-[d]	1
Southland	90	50	50	63	90	20	50	53	3	3	-	3
Liso	90	70	50	70	90	20	20	43	3	2	-	3
Manchar	90	50	70	70	90	20	70	60	2	4	-	3
Latar	50	70	--	60	20	50	--	35	3	2	-	3
Commercial	70	50	20	70	70	50	70	63	2	3	-	3
Potomac	90	70	20	60	70	50	70	63	1	1	-	1
Pennlate	70	50	--	60	70	50	--	60	3	4	-	4
Reed canarygrass												
Frontier	90	70	90	83	70	50	90	70	1	2	1	1
Commercial	90	90	90	90	70	70	70	70	2	1	2	2
Ioreed	90	70	90	83	70	50	70	63	2	2	2	2
Timothy												
Itasca	20	20	20	20	70	70	70	70	1	1	1	1
Clair	20	20	20	20	20	70	70	53	2	2	2	2
Tall fescue												
Alta	90	90	90	90	70	70	90	77	1	1	1	1
Goars	90	90	90	90	70	70	70	70	2	2	3	2
Kentucky G1-232	90	90	50	77	70	70	70	70	3	2	2	2
Crested wheatgrass												
Fairway	--	--	--	--	--	--	--	--	-	-	-	-
Standard	--	--	--	--	--	--	--	--	-	-	-	-
Commercial	--	--	--	--	--	--	--	--	-	-	-	-
Intermediate wheatgrass												
South Dakota 20	20	--	--	20	90	--	--	90	3	-	-	3
Greenar	70	--	--	70	90	--	--	90	1	-	-	1
Amur	50	--	--	50	50	--	--	50	2	-	-	2
Commercial	70	--	--	70	90	--	--	90	2	-	-	2

Table 2. Continued

Strain or variety	Stand[a] reps. 1	2	3	Ave.	Growth[b] reps. 1	2	3	Ave.	Rating[c] reps. 1	2	3	Ave.
Tall wheatgrass												
Commercial	50	70	90	70	20	70	90	60	3	1	1	2
Alkar	70	70	90	77	70	70	70	70	1	1	2	1
Utah	70	70	70	70	70	70	50	63	2	1	3	2
Pubescent wheatgrass												
Utah 109	--	--	--	--	--	--	--	--	-	-	-	-
Commercial	--	--	--	--	--	--	--	--	-	-	-	-
Topar	--	--	20	20	--	--	20	20	-	-	-	-
Russian wild ryegrass												
P-9012	--	--	--	--	--	--	--	--	-	-	-	-
Vinall	--	--	--	--	--	--	--	--	-	-	-	-
Clover												
Commercial biennial yellow sweetclover	90	90	90	90	90	70	70	77	-	2	-	2
Commercial alsike	20	70	50	47	20	50	50	40	-	-	-	-
Commercial white dutch	50	20	70	47	20	20	50	30	-	-	-	-
Commercial strawberry	70	70	50	63	20	20	20	20	-	-	-	-
Commercial ladino	20	50	--	35	20	50	--	35	-	-	-	-
Spanish biennial white sweetclover	70	90	70	77	90	70	70	77	-	2	-	2
Commercial biennial white sweetclover	70	90	70	77	90	90	70	83	-	1	-	1
Low cumarin biennial white sweetclover	70	70	70	70	70	70	70	70	-	2	-	2
Birdsfoot trefoil												
Granger	70	70	90	77	50	50	70	57	-	-	-	-
Cascade	70	70	90	77	50	50	70	57	-	-	-	-
Red clover												
Penscott	70	50	50	57	50	50	70	57	-	-	-	-
Kenland	70	50	50	57	50	50	70	57	-	-	-	-
Commercial	70	50	50	57	50	50	70	57	-	-	-	-

Table 2. Continued

Strain or variety	Stand[a] reps. 1	2	3	Ave.	Growth[b] reps. 1	2	3	Ave.	Rating[c] reps. 1	2	3	Ave.
Alfalfa												
Ladak	90	90	70	83	70	70	50	63	-	-	-	-
Atlantic	90	70	70	77	70	70	50	63	-	-	-	-
Brand 919 noculized	90	70	90	83	70	70	50	63	-	-	-	-
Brand 919	90	70	90	83	70	70	50	63	-	-	-	-
Rhizoma	50	70	20	47	70	70	50	63	-	-	-	-
Buffalo noculized	90	70	70	77	70	70	50	63	-	-	-	-
Buffalo	90	70	70	77	70	70	50	63	-	-	-	-
Terra verde noculized	90	70	70	77	70	70	50	63	-	-	-	-
Terra verde	90	70	70	77	70	70	50	63	-	-	-	-
Lahontan	90	50	70	70	70	90	50	70	-	-	-	-
Rambler	90	70	70	77	50	70	70	63	-	-	-	-
DuPuits noculized	90	70	70	77	90	90	70	83	-	-	-	-
Ranger	90	70	70	77	70	70	50	63	-	-	-	-
Ranger noculized	90	70	70	77	70	70	50	63	-	-	-	-
African	20	20	50	30	50	50	50	50	-	-	-	-
Grimm	70	90	70	77	70	70	50	63	-	-	-	-
Grimm noculized	70	90	70	77	70	70	50	63	-	-	-	-
Syn. C	20	50	70	47	50	70	70	63	-	-	-	-
Narragansett	90	70	90	83	70	70	70	70	-	-	-	-
Nomad	90	70	50	70	20	50	20	30	-	-	-	-
Vernal	90	70	70	77	70	70	50	63	-	-	-	-
Moapa	50	70	50	57	50	50	50	50	-	-	-	-
DuPuitz	90	50	70	70	90	50	70	70	-	-	-	-
Miscellaneous												
P-27 Siberian wheat-grass	--	--	--	--	--	--	--	--	-	-	-	-
Tualatin tall oat-grass	50	50	90	63	70	70	70	70	-	-	-	-

Table 2. Continued

Strain or variety	Stand[a] reps. 1	2	3	Ave.	Growth[b] reps. 1	2	3	Ave.	Rating[c] reps. 1	2	3	Ave.
Miscellaneous (Cont.)												
Commercial red top	20	--	--	20	70	--	--	70	-	-	-	-
Sodar streambank wheatgrass	--	--	--	--	--	--	--	--	-	-	-	-
Commercial meadow foxtail	--	20	20	20	--	20	50	35	-	-	-	-

[a]Percent stand--percent of full stand in increments of 10 (0-100).

[b]Percent growth--in increments of 10 (0-100).
Grasses--percent of highest yielding grass
Legumes--percent of highest yielding legume

[c]Strain rating on growth--where there is more than one strain of a variety, rank the strains on comparative growth such as 1st, 2nd, etc.

[d]Dash mark means no stand or we were unable to rank varieties.

Table 3. Yield of hay from a pasture mixture, alta fescue and Reed canarygrass

Plot	Yield (T/A)
Pasture Mix 5 Acres	2.52
Alta Fescue 2.5 Acres	3.24
Reed Canarygrass 2.5 Acres	2.37

The yields were calculated by counting the bales harvested from each plot on July 1, 1965. These were not replicated.

Each plot received approximately 25 pounds of phosphorus per acre in October 1964 and 42 pounds of nitrogen per acre in March 1965.

Table 4. Yield of hay from a pasture mixture treated with amendments and fertilizers

Plot No.	Treatment	Yield[a] (T/A)
1	NP	2.43
2	2T gyp/A + NP	2.11
3	P	2.29
4	IT/A gyp + NP	2.94
5	Sulfur + NP	1.70
6	NP	2.43
7	IT gyp/A + NP	3.13
8	Sulfur 1000#/A + NP	3.10
9	P	3.21
10	2T gyp/A + NP	2.94

[a]Yield was determined by counting the bales. These were not replicated.

IRRIGATION

Sprinkler irrigation was studied in conjunction with the pasture mixture experiment planted in 1962.

In order to achieve a very short irrigation interval during germination, gross applications of 0.64 inches every six days were employed for seven irrigations. It was considered that deeper irrigations might have been more beneficial for leaching the salts out of the surface soil.

A heavy rainfall during the mid-portion of the season and one near the end appeared to cancel whatever significant surface texture differences might have been evident due to application rates of 0.16 and 0.32 inches per hour that were used.

A total of 8.4 inches of gross irrigation was applied between June 5 and September 1, and 0.8 inches rain fell during this period. The average net change in the water-table elevation was of 1 foot rise between July 6 and September 8 (4).

FROSTS

The closest meteorologic station for the area is the one situated at the KVNU Radio Station which has operated since 1957.

The minimum temperatures recorded and the dates of occurrence for the months of April through September are as follows:

Year	April		May		June		July		August		September	
	°F	Day	°F	Day	°F	Day	°F	Day	°F	Day	°F	Day
1957	26	27	33	4	36	14	43	4	44	31	31	20
1958	21	7	36	2	36	4	44	1	26	31	26	25
1959	20	9	26	21	38	30	40	4	39	22	29	3
1960	21	17	20	24	30	21	44	9	34	23	35	25
1961	19	14	22	7	40	3	42	1	48	13	28	23
1962	27	30	31	1	32	7	47	28	37	31	31	30
1963	23	16	39	11	30	23	44	1	45	29	41	27
1964	24	17	27	4	40	22	--	--	34	30	28	27
1965	28	23	22	8	40	17	44	13	34	31	22	18
1966	14	27	26	23	34	25	46	9	38	28	36	16
1967	10	28	22	1	41	11	42	16	41	20	29	13
1968	19	8	22	11	35	30	39	3	36	16	30	24

From the above data it is evident that frosts can be expected during the month of June, which can affect both the yield and the quality of barley. The same could be said for the hay crops, although the damage would be less serious.

ACTUAL SITUATION

There are several other areas in the state with conditions similar to Cache Valley because of their parallel geologic history.

It seems evident that irrigation water must be applied in carefully controlled amounts to avoid raising the water-table to critical levels. In addition, some water must move down carrying with it excess salts. Neither of these objectives can be easily met because of the natural conditions. The use of tile drains is a possible solution but is not considered economically feasible. The highly impermeable sub-soil would require tiles at very close spacing to be effective. Plastic mole drains cost much less and can be placed at much closer spacing than tile drains. However, before mole drains can be widely used, additional improvements must be made in present designs and methods to assure effective and reliable operation over long periods of time.

Some improvement in productivity of this land might be affected without drainage just by applying water in carefully controlled amounts. Sprinkler irrigation may be one way to adequately control the amount of water added or perhaps carefully controlled border and furrow irrigation can be used.

In addition to control of the water-table, there are other factors involved such as salt accumulation, soil fertility, use of soil amendments, and tillage practices.

In a visit to the Drainage Farm on July 26, 1968, the following observations were made on the different soils present:

1. Salt Lake silty clay, deep very poorly drained soil, fine textured salt, and alkali affected. Where the surface water has been controlled and the top soil is dry, barley presented a good stand uniformly maturing. The rest is a natural meadow with water standing at the surface.

2. Greenson loam, moderately well and imperfectly drained. Alfalfa Reed canarygrass mixture presented a good stand where no surface water was present. Under surface water conditions, Reed canarygrass was well established. Barley growing where the water is close to the surface presented many weedy spots and different stages of maturity.

3. Airport-Salt Lake complex, slowly permeable with high concentration of salt and alkali in the sub-soil. Reed canarygrass is well established under a surface water condition. Barley presents a poor stand affected by water close to the soil surface.

Changes in the farm, as a result of surface water control that permitted the establishment of crops, can be seen in the different aerial photographs (Figures 5a, 5b, 6, 7a, 7b, and 8) taken in 1946, 1953, 1959, and 1966.

Figure 5a. Aerophotograph taken August 7, 1946, AAI-2B-151.
The future USU Drainage Farm shows no activity.

Figure 5b. Aerophotograph taken August 7, 1946, AAI-2B-151.
The USU Drainage Farm and selected surrounding areas show no activity.


8-7-46
AAI-2B

Figure 6. Aerophotograph taken September 4, 1953, AAI-10K-21. This photo shows no changes in the farm compared with Figure 5a.


-4-53
AAI-

Figure 7a. Aerophotograph taken July 5, 1958, AAI-2W-76. The open drain, constructed June 1958, and the water collecting ditches can be seen.

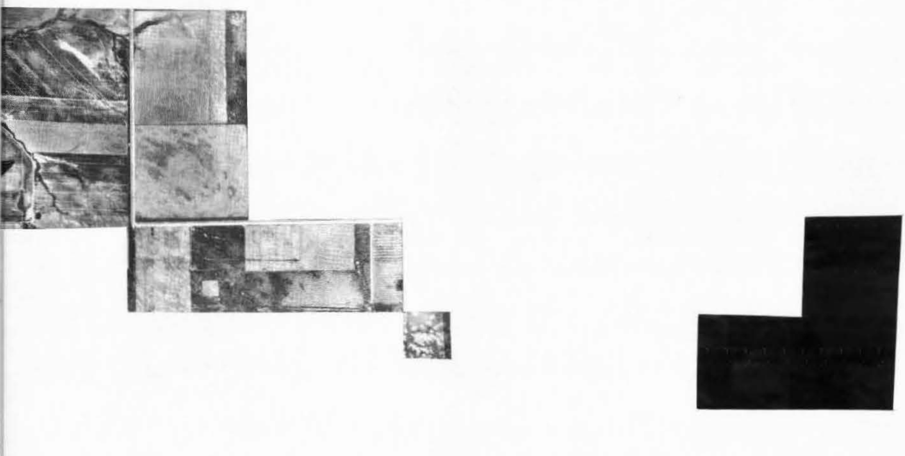


Figure 7b. Aerophotograph taken July 5, 1959, AAI-2W-76.
The influence of the open drain on the surrounding area is seen to the northwest of the USU Drainage Farm. Activity on the farm has sparked interest in the area.


7-5-59

Figure 8. Aerophotograph taken May 1, 1966, AAI-2GG-89. In this photo we have the USU Drainage Farm with its plots of alfalfa, grasses, and barley. The improvement in the area appears evident. It can be noted that the gullies in the western part have been reduced and the land is under tillage. This photo was taken early in the season, and the activity in the whole area is not noticeable.


5-1-66
AAI-2

PROPOSAL FOR DEMONSTRATION FARM DEVELOPMENT

Considering the different features that characterize the area, it seems that the most appropriate use of these lands is to grow forage crops and to establish grasslands for beef or dairy cattle production.

Continuous tilling of these soils would most likely affect the physical conditions and make it more difficult to control ground water than using permanent crops with a well designed irrigation drainage system. These together with the occurrence of frosts during the month of June make it advisable not to grow sensitive nor culture requiring crops.

Water Supply

The area of the farm to be irrigated is about 106 acres from which 88 acres would be occupied by alfalfa and 18 acres by barley. Considering a consumptive use of 24 inches for alfalfa, the net water requirement deducting 2 inches upflow, 4 inches rainfall during the growing season, and 4 inches stored during winter would be 14 inches or 102 acre feet. For barley, assuming 16 inches of seasonal consumptive use, the net amount required would be 9 inches after deducting 1 inch water flow, 4 inches winter storage, and 2 inches rainfall during the growing season. The total needed is 117 acre feet which can be provided by a stream of 1 cubic foot per second flowing 16 hours every day. This would provide for a 5 inch irrigation every three weeks.

Assuming a 65 percent irrigation efficiency, 1.6 cfs at the well would be the total needed flow.

Fertility

Reclaimed lands as the Utah State University Drainage Farm undergo many changes in their physical and chemical characteristics, so recommendations for fertilizers must be made considering the cropping history and the management of each particular plot together with chemical analyses. Due to a lack of recent analyses it is difficult to give suggestions for fertilizing practices (5).

Crops and Rotation

Hay and barley would be the crops grown in a six-year rotation, distributed in five years for alfalfa and one year for barley. Actually the rotation period would be determined by the condition of the alfalfa stands, maintaining them as long as their yields do not go below an economic level.

The Lahontan alfalfa variety, because of its resistance to the stem nematode and its constant outstanding behavior throughout the state, should be planted at a rate of 8 pounds per acre (6).

Three cuttings for hay in June, July, and September should give a total yield of from 5 to 6 tons per acre.

A second hay crop could be alfalfa-intermediate wheatgrass mixture planted at rates of 6 to 8 pounds per acre of alfalfa and 4 pounds per acre of intermediate wheatgrass.

The above mentioned hay crops, as well as barley, should be sown on drained and leveled land.

The field at the southeast of approximately 10 acres could be maintained as a grazing area planted to Reed canarygrass, tall fescue, and tall wheatgrass, the latter in the high salty spots. Grazing should be controlled so the grasses do not become tough and unpalatable nor deteriorate by overgrazing. This field would constitute a demonstration for areas where leveling and drainage is difficult to accomplish.

Cattle Carrying Capacity

Considering 800-pound animals with a daily requirement of 29,000 kcal. per head, it would be possible to maintain 170 head according to the following annual feed production:

Alfalfa,	88 acres yielding about	530 tons hay, representing about	150 head
Barley	18	21 tons grain	10
Grazing	10		10

The cattle would be fed in installations built for that purpose and for confining them most of the time. Grazing would depend upon management factors, mainly, vegetative stage of the grasses and maintenance of the stand. The 106 acre irrigated area would preferably not be grazed.

Irrigation System

In applying irrigation water, the main thing to take care of is to prevent the water-table from rising. Sprinkler irrigation would be the best for uniform water distribution. Border irrigation could also be practiced in which case borders would have to be 50 feet apart and 1,200 feet long. Figure 9 illustrates this.

Frequency of Irrigation

Considering the soil to be moistened to 5 feet depth, when half of the available water is depleted and 0.22 inches consumed dailey, the periods between irrigations would be three weeks for alfalfa. During the first part of the vegetative growth, barley can be irrigated when 60 percent of the available water storage capacity in the soil explored by the roots is depleted. Near maturity, irrigating when 80 percent of the available water is depleted would fill the plant requirements. Roughly, three irrigations at initial internode elongation, boot, and grain milk stages would be sufficient (3).

Surface Drainage

Control of the surface water was demonstrated to be the most important measure for controlling the water-table. The sources of surface water are two: that entering from surrounding areas and the excess water applied in irrigation. The upward flow has been considered negligible in incrementing surface water.

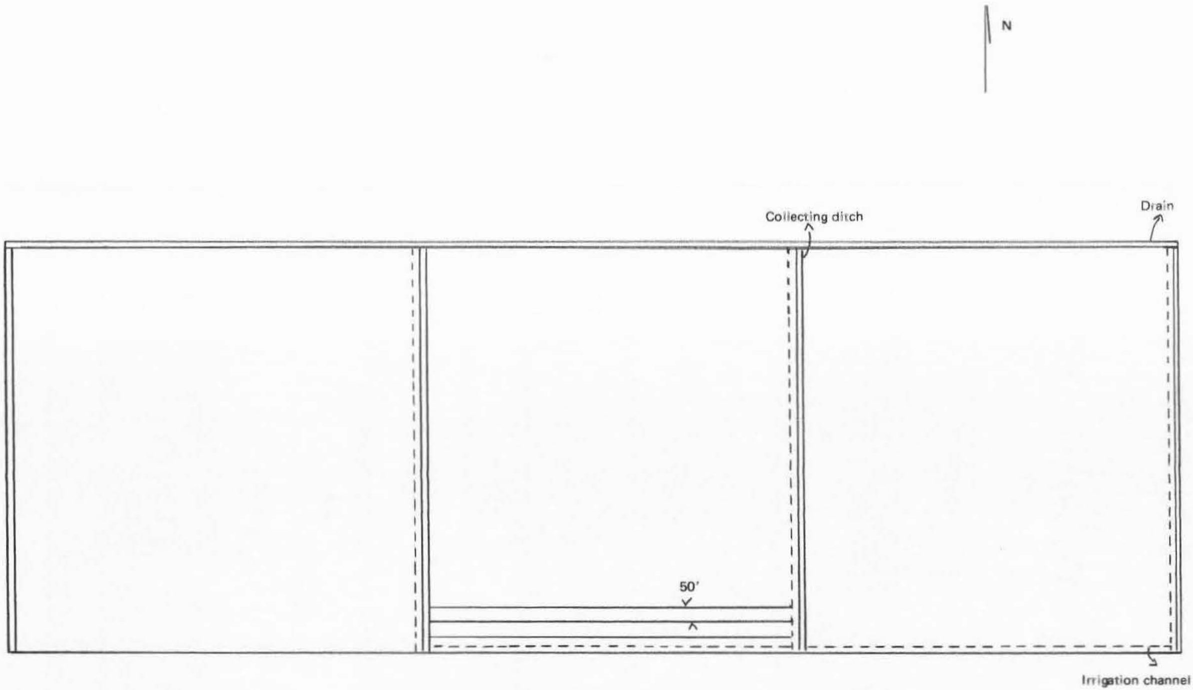


Figure 9. Scheme for border irrigation and collecting ditches.

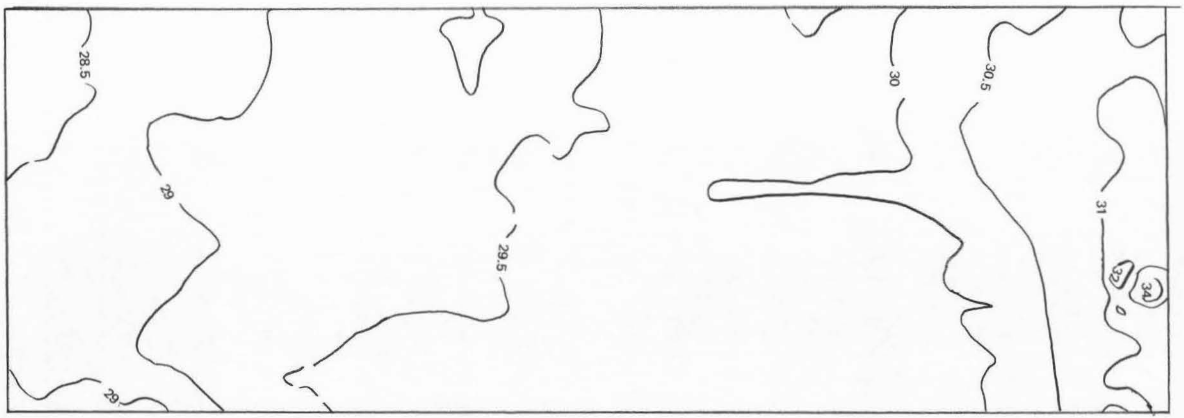


Figure 10. Topographic map

It is important to complete and connect with the main open drain those drains which intercept run-off water. If border irrigation is practiced, excess water collecting ditches will be required at the ends of the borders.

The area to be grazed should also be provided with collecting waterways to eliminate surface standing water.

Sub-surface Drainage

Deep leaching is prevented by the existing artesian pressure. Mole drains present a problem of instability. Recommendations for their use depends upon the availability of a more durable lining material.

Tile drain utilization appears economically unpracticable.

LITERATURE CITED

1. Bishop, A. A. Cache irrigation and drainage. Annual Reports, Project No. 285, Utah State Engineering Experiment Station, Logan, Utah. 1958, 1959, 1960.

2. Harrison, R. D. District Conservationist, United States Department of Agriculture Soil Conservation Service, Logan, Utah. Personal interview. August, 1968.

3. Israelsen, O. W. Irrigation principles and practices. John Wiley & Sons, New York. 1965. 447 p.

4. Keller, J. Effect of various irrigation techniques on soil aeration, soil structure and crop response. Annual Report, Project No. 591, Utah State Engineering Experiment Station, Logan, Utah. 1962.

5. Lamborn, R. W. Research Associate in Soils and Meteorology Department, Utah State University, Logan, Utah. Personal interview. November, 1968.

6. McAllister, D. R. Professor of Agronomy, Plant Science Department, Utah State University, Logan, Utah. Personal interview. December, 1968.

7. Peterson, H. B. The improved use of wet and salted soils for forage production. Annual Reports, Project No. 376, Utah State Agricultural Experiment Station, Logan, Utah. 1961, 1962, 1963, 1964, 1965.

8. Peterson, W. Ground water supply in Cache Valley, Utah. Utah State University Extension Service Bulletin N.S. 133. August, 1946.

9. Wilson, L. Classification and characterization of Utah soils for improved utilization. Annual Report, Project No. 317, Utah State Agricultural Experiment Station, Logan, Utah. 1958.